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Ceramic HEPA Filter Program

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Ceramic HEPA Filter Program

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Mark Mitchell et al.

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LLNL Ceramic HEPA Filter Program

- Potential benefits of ceramic filters in nuclear facilities
 - Short term, intermediate, long term benefits
 - Benefits of Ceramic Filter Technology
- History
 - International R&D
 - U.S. R&D
- Results
 - ATI Test Results
 - ICET Testing – forthcoming
- Current Technical Developments & Path forward
 - Testing at LLNL, ATI, and ICET
 - Filter, component, and material testing at Cal Poly's High Temperature Test Unit (HTTU)
 - Nanofiber R&D at LLNL
- Conclusion
- Thanks

Potential Benefits of Ceramic Filters

- Ceramic HEPA filters should survive higher temperatures and fires better than existing technology
- Short term benefit for DOE, NRC, and industry
 - Cal Poly High Temperature Test Unit (HTTU) provides unique testing capability
 - Materials, components, filter testing with high temperature air flow
 - Capability for testing components to simulate a facility subjected to an earthquake followed by a fire (aka shake-n-bake test)
- Intermediate term benefit for DOE, NRC, and industry
 - Spin-off technologies applicable to other commercial industries
 - Filtration for specialty applications, e.g., explosive applications
- Long term benefit for DOE, NRC, and industry
 - Engineering solution to safety problem
 - Improvements in filter performance (e.g., heat and fire resistant) will improve facility safety and decrease dependence on associated support systems
 - Large potential life-cycle cost savings
 - Facilitates development and deployment of LLNL process innovations to allow continuous ventilation system operation during a fire

Benefits of Ceramic Filter Technology

- Overcomes problems with existing technologies in DOE facilities
 - Existing HEPA filters result in significant design, operational, and compliance costs for associated fire protection and support systems
 - Defense Nuclear Facilities Safety Board (DNFSB) correspondences and presentations by DNFSB members highlighted need for HEPA filter R&D
 - DNFSB Recommendation 2009-2 highlights this issue for a nuclear facility response to an evaluation basis earthquake followed by a fire (LANL PF-4)
 - DNFSB comments on a new facility under construction (CMRR) highlighted significance of HEPA filter issues and escalated costs (note current status of CMRR)
 - DNFSB comments continue in 2012
- Advantageous to focus on engineering safety solutions rather than primarily additional DSA analysis
 - Increase safety and performance, while significantly lowering cost
 - Reduce or eliminate safety basis costs associated with safety class and safety significant systems in nuclear facilities
 - Fire suppression, fire detection and alarm, and internal building structure
 - Provide protection for acidic fume environments in nuclear facilities
 - Formerly protected by Teflon™ pre-filters (prior to DNFSB comments)

Bottom Line



1957 & 1969 Rocky Flats Fires

- DOE Complex Needs Analysis
 - 100% of knowledgeable nuclear air cleaning professionals believe HEPA filter media strength is very, or extremely, important
 - 92% of knowledgeable nuclear air cleaning professionals believe it is important to develop alternatives to current glass-fiber filters

1980 fire, note performance of existing high temperature HEPA filters

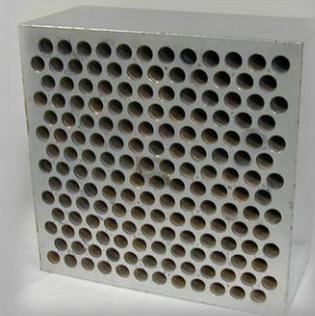
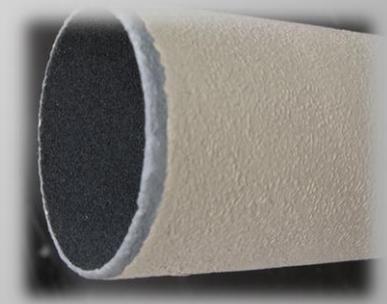
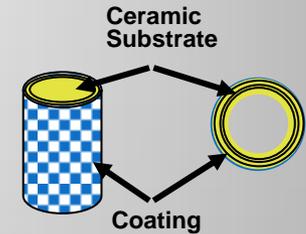


History of Ceramic HEPA Filter Program

- LLNL has conducted research into more advanced HEPA filters for more than 30 years, e.g.,
 - Metal HEPA filters, Dr. Werner Bergman et al.
- International R&D
 - Mark Mitchell & Dr. Werner Bergman initiated the ceramic HEPA filter research, including work by Russian national institutes
 - Bochvar, Bakor, and Radium Khlopin Institute
 - Resulted in ceramic HEPA filter proof-of-concept
- Current U.S. R&D (NSR&D)
 - Goal: Develop a fire resistant filter with better performance (e.g., heat, flame, moisture, corrosion, loading)

Current Program Status

- Completed international R&D tested a wide variety of ceramic substrates, coatings, and technologies to apply coatings
 - Down selected two filter technologies
 - LLNL testing Russian filter prototypes
 - Mini-assembly (8.5"x8.5"x11.5")
 - Full-scale assembly (2'x2'x11.5")
- Ongoing University Collaboration (CalPoly)
 - Enhanced testing capability - High Temperature Test Unit (HTTU)
 - HTTU provides an unique capability to test binders, sealants, and frames
 - See separate presentation on HTTU
 - Tooling capability to replace individual tubes in support of R&D and manufacturing
- LLNL R&D
 - Invented new sealants to be tested at Cal Poly (HTTU)
 - Invented new filtration coatings
 - Commercial procurements of ceramic substrates
 - Innovative new coatings lab at LLNL
 - Nanofiber coating apparatus designed, fabricated, installed, and in testing



International R&D - Nonproliferation

- Intended to be a self-sustaining enterprise for the long term employment of scientists, engineers, and technicians
- Russian R&D nuclear and ceramics capabilities
 - Bochvar
 - Leading Russian institute conducting research on fuel cycle technologies & fissile materials processing
 - Founded in 1945 to solve materials science and technology problems related to the production of nuclear weapons, capabilities in ceramic technology, emphasis on applied technology at large scales
 - Radium Khlopin
 - Developed reprocessing technologies for fissile materials production
 - Conducts R&D for the nuclear industry, analytical laboratory services, environmental investigations of nuclear tests, designs accident response procedures and produces isotopes
- Goal
 - Develop ceramic HEPA filter technology
 - Establish working relationship between U. S. industrial partner and Russian nuclear laboratories
 - Long term employment of Russian WMD scientists, engineers, and technicians to fabricate ceramic HEPA filters for U. S., Russian, foreign markets, and conduct ongoing R&D services

Monitoring Russian Research



Russian R&D Explored and Down Selected Ceramics and Designs for Membranes and Substrates



Filter Element with Aluminum-Oxide Membrane Made by Gas-Plasma Spraying Method



Fiber-Structured Filtering Element Samples



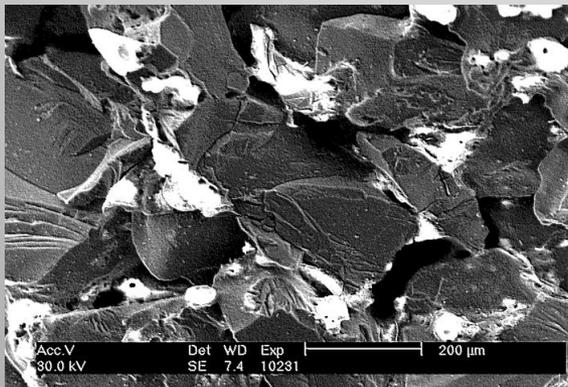
Various ceramic samples

Research included:

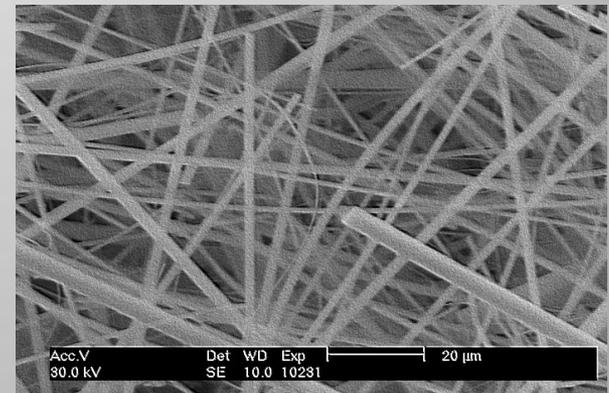
- Variety of Alumina Electrocorundums
- Disthene-Sillimanite
- SiC (numerous approaches) substrate
- Aluminum oxide substrate
- Preparation techniques such as slurry molding, casting, plasma deposition, proprietary vacuum deposition

Early Russian Filter Development

- Porous SiC substrate considered for increased strength
- Balance filtration efficiency and pressure drop utilizing the characteristics of the substrate and the coating
 - Sintered powder substrate has low efficiency and high pressure drop, but high strength
 - Fibrous substrates have moderate efficiency and low pressure drop, but low strength

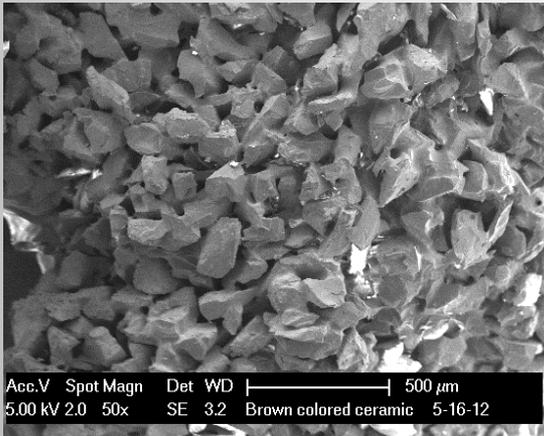


Early SiC cylinder

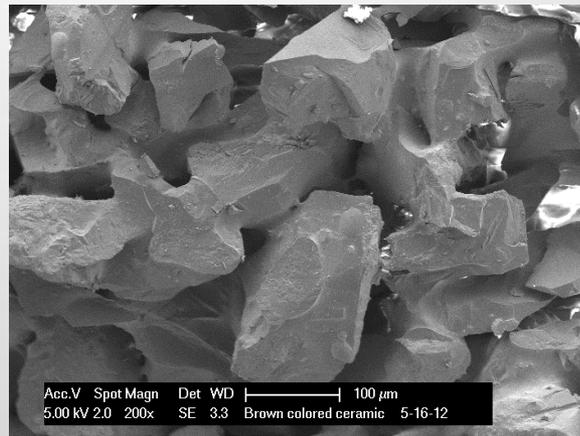


Photomicrograph of early fiber research

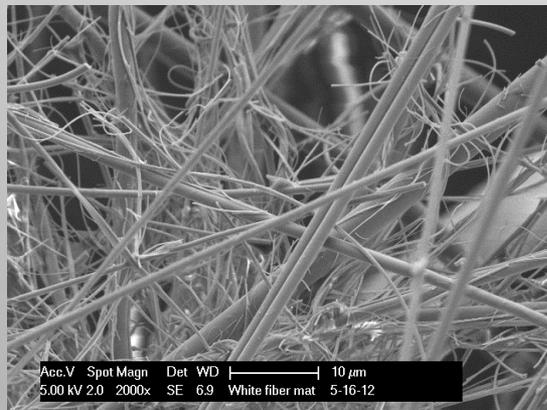
SEM of final substrate and coating – Russian proof-of-concept



Final prototype substrate



- Substrate has large, well bonded grains
 - Strength
 - Large porosity



Final filter media

- Filter media is composed of fine fibers
 - Nominally many are sub-micron
 - Smaller fibers should increase efficiency and lower dP

Russian filter proof-of-concept



Mini-Assembly



Full-Scale Assembly

- Ceramic HEPA filter in metal housing
- Weight
 - Mini-assembly
14.3 lbs / 4.5 kg
 - Full scale (Class 5)
110 lbs / 50 kg

Russian filter proof-of-concept Testing at ATI



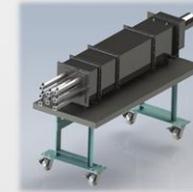
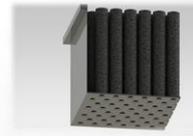
- Successful proof-of-concept
- Independent verification of HEPA filtration (> 99.97% filtration efficiency) at
 - 30 cfm (dP 2.8")
 - 71 cfm (dP 6.1")
- Unsatisfactory dP
 - R&D of filter media coatings at LLNL to reach final goal

Russian filter proof of concept- Testing at ICET forthcoming



- Plan to utilize the currently developed test stand used to qualify metal HEPA filters for AG-1 Section FI to also qualify ceramic HEPA filters

Current Technical Developments

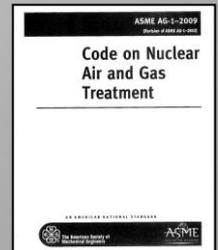


- Developing ceramic HEPA filter technology meeting specifications of existing nuclear grade HEPA systems
 - Three Main Projects
 - Ceramic HEPA Filter Testing at LLNL, ATI, and ICET
 - University Collaboration (Cal Poly) student projects to develop improved testing capabilities (HTTU provides an unique capability to test binders, sealants, and frames)
 - Filter media research at LLNL to reduce dP and maintain filtration efficiency
 - Intellectual Property
 - Portfolio of over a dozen inventions and patents

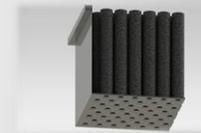
Current Technical Developments - Testing

- Prototype Ceramic HEPA Testing at LLNL, ATI, and ICET
 - ASME 510 leak test at LLNL industrial hygiene laboratory
 - Scanning individual components and assembled HEPA filter
 - Certification testing at ATI complete
 - Future filters will likewise be sent to ATI for testing
 - Next step: ICET qualification testing of Russian proof-of-concept filters
 - Future filters will likewise be to ICET
 - Pave the way for revised regulations

New ASME AG-1 Section for Ceramic Filters and DOE-STD-3020 revision



Current Technical Developments – Cal Poly

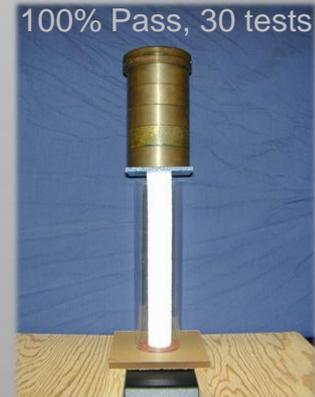


- Tooling Project – Complete
- High Temperature Testing Unit (HTTU) to study HEPA filter behavior as effected by fire conditions
 - HTTU provides an unique capability to test binders, sealants, and frames
 - Primarily targeted for ceramic filters, but can support studies of non-ceramic filters if desired
 - Status
 - Design HTTU and Control System – Complete
 - Fabrication, test and demonstrate HTTU – In progress
 - Install and test controls & instrumentation for HTTU – In progress
 - Conduct experiments on various HEPA filter materials and designs
 - Better sealants, binders, and other components (e.g., frames)
 - Question: Any interest in integral welded frame with a flat sealing surface instead of bolted frame?
 - Question: Any interest in shake-n-bake test capability?

Current Technical Developments – Nanofibers



- Nanofiber coatings research
 - Reduce pressure drop while maintaining filtration efficiency
 - Develop and test improved filtration materials for ceramic filters using LLNL/DOE developed innovations
 - Research contract fabrication opportunities - Complete
 - Procured R&D quantity of substrate elements (tubes)
 - Proof test (compressive strength) tubes - Complete
 - Measure dP of tubes at flow rates required by 3020
 - Complete for substrates
 - Developed deposition system for coating tubes
 - Coating R&D - In progress



Conclusions

- Research has short, intermediate, and long term benefits to DOE Complex, NRC, and industry
- Completed Russian R&D and successful proof-of-concept
- Ceramic HEPA Filter Program is developing unique capabilities to answer complex questions
- Path forward
 - Testing of binders, sealants, and frames (see Cal Poly presentation)
 - Development of filter media to reduce dP and maintain filtration efficiency
 - Portfolio of over 12 inventions with provisional patents already filed
- We will continue to pursue NSR&D funding for this program
- We welcome suggestions for future research ideas to best fit your needs

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- Ron Beaulieu, NSTec Safety Basis Program Leader (formerly LLNL)
- Paris Althouse, LLNL, GIPP Program Leader
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